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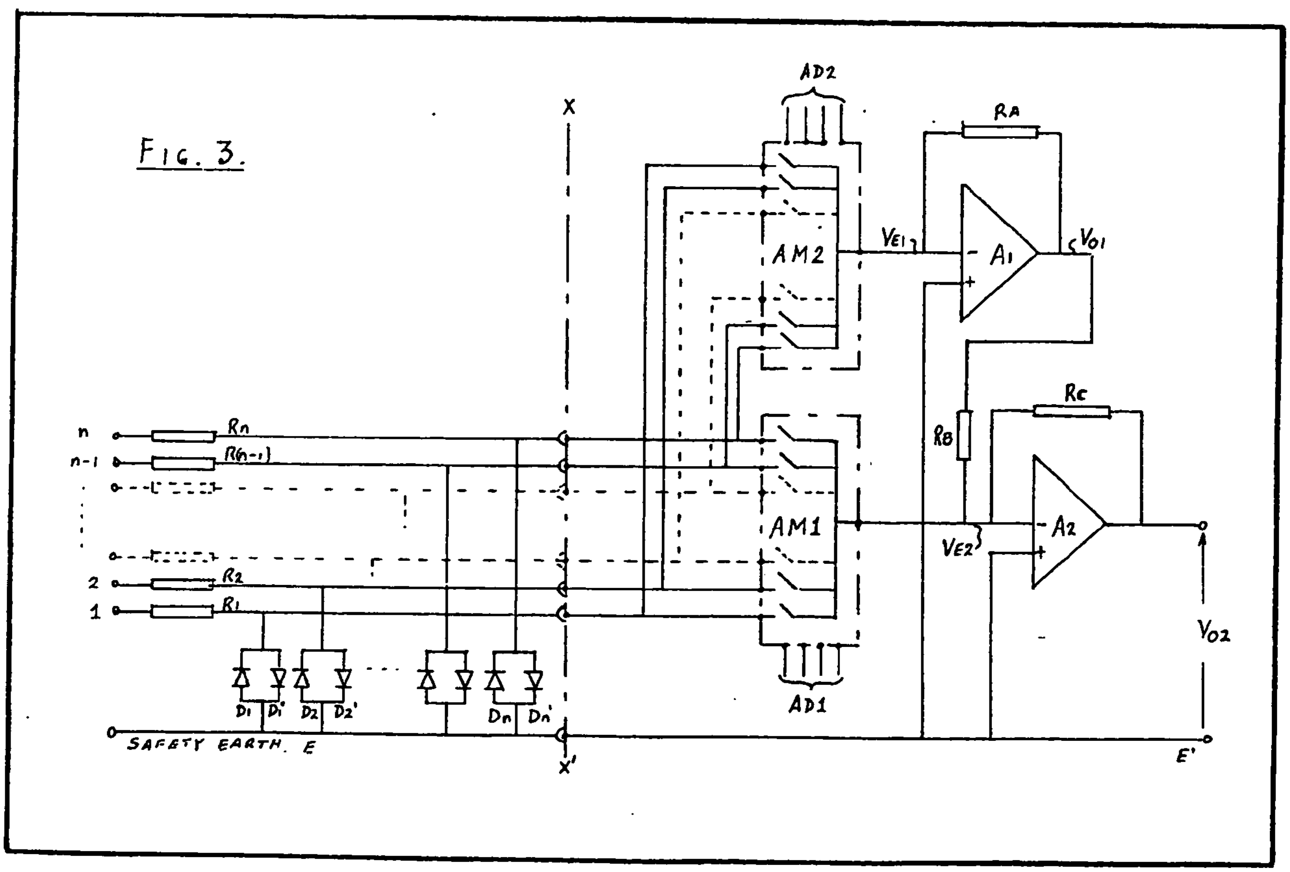
(54) Measuring potential difference

(57) The invention describes a two part multiplexed measurement system capable of measuring voltages between any two selected points 1—n within a power system by differencing currents produced by the voltages at those points via resistors R_1—R_n into an amplifier system A_1, A_2 which inerently reproduces a scaled replica V_{02} of the voltage waveform between the two points selected but at a safe voltage with respect to safety earth.

The arrangement of diode pairs D, D′ in the two part system shown is such that when the interconnecting plug at XX′ between the two parts of the system is disconnected no conductor of the plug or socket thus exposed has a voltage greater than one volt with respect to safety earth. Furthermore shorting of any conductor to any other at the exposed plug and socket cannot cause damage or malfunction to the power system or the monitoring equipment.

Fig. 3.



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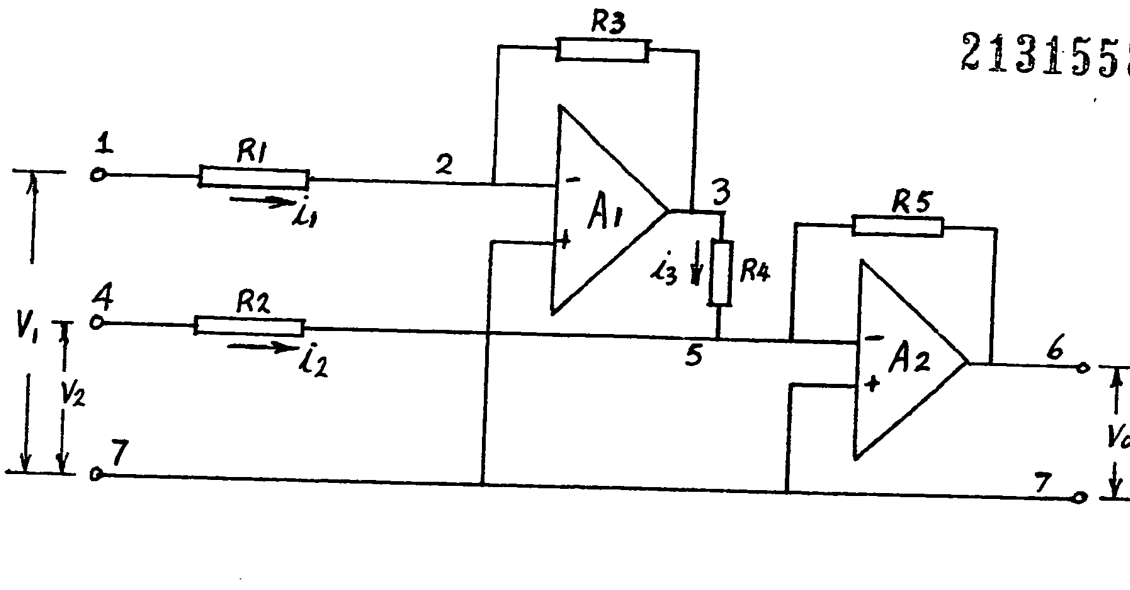

FIG. 1.

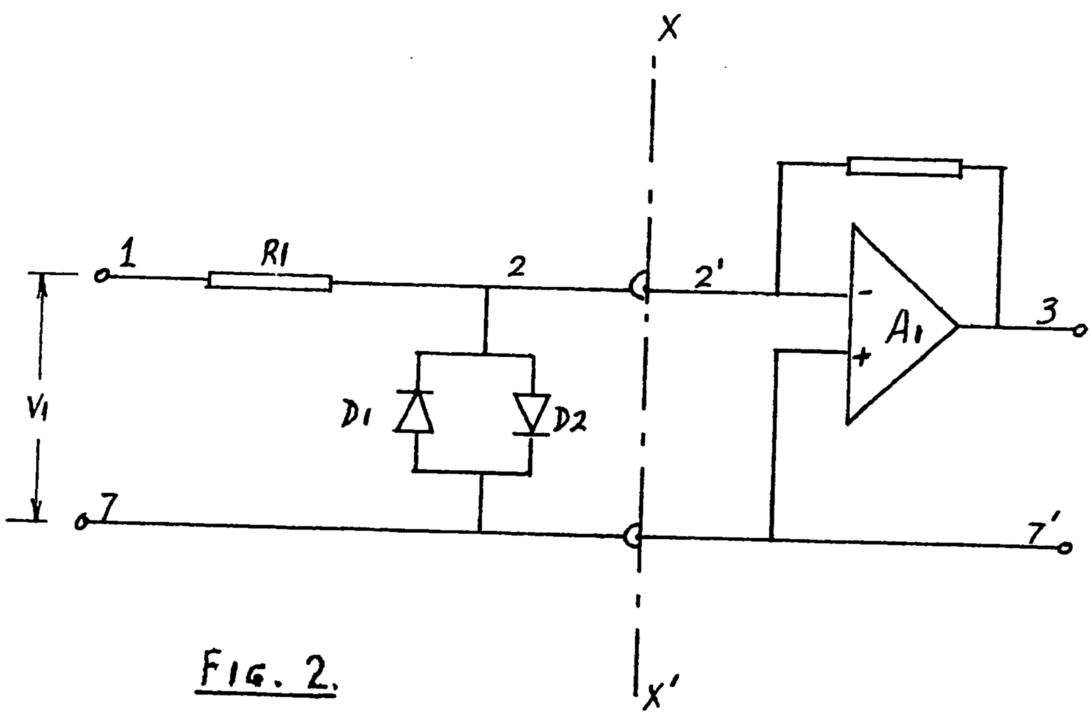

FIG. 2.

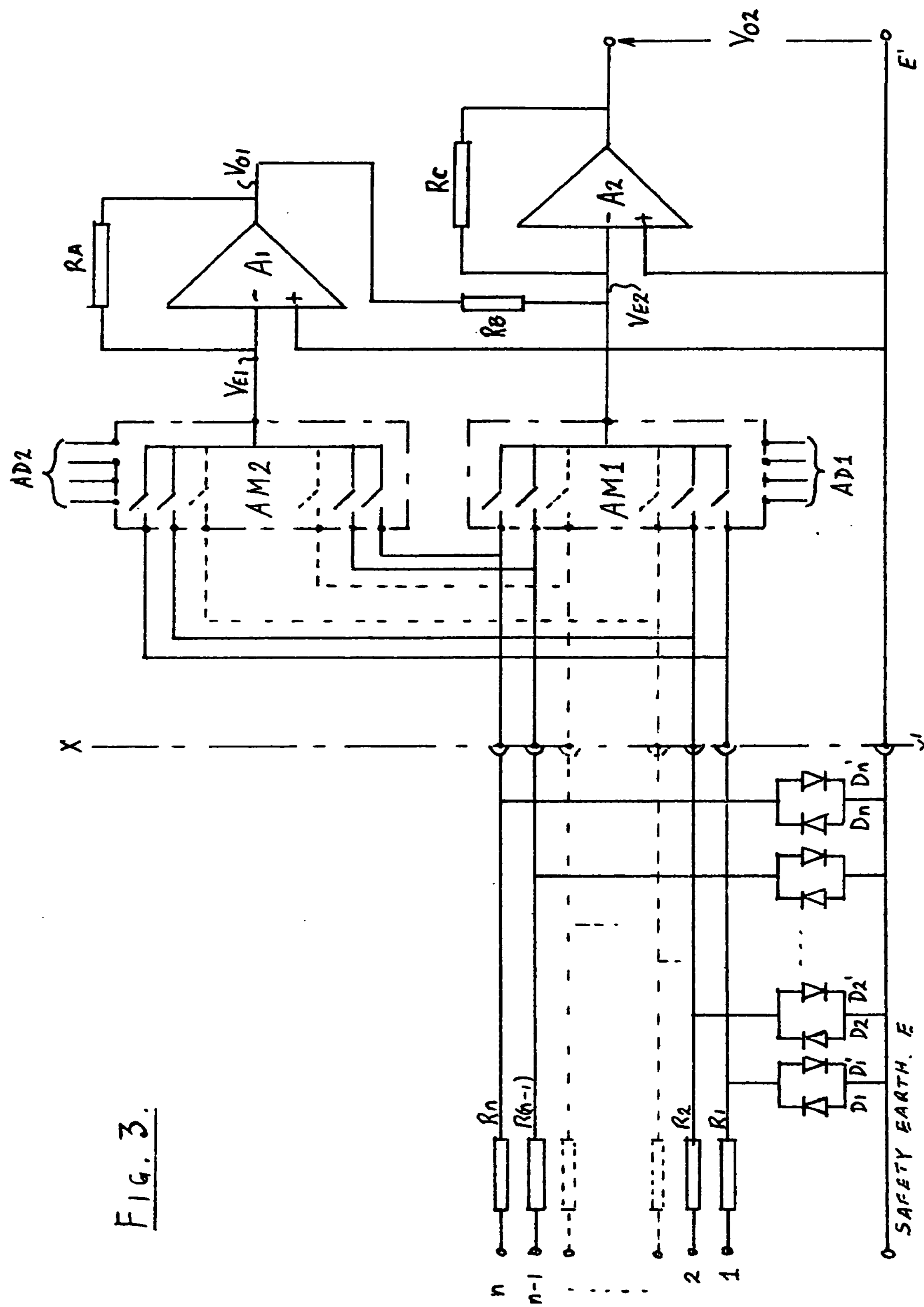
V_{O2}
E'
V_{O1}
R_A
R_C
A_1
A_2
R_B
V_{E1}
V_{E2}
AD2
AM2
AM1
AD1
X
X'
D_n'
D_n
D_2'
D_2
D_1'
D_1
SAFETY EARTH E
R_n
$R_{(n-1)}$
R_2
R_1
n
n-1
2
1

FIG. 3.

SPECIFICATION

A safe multi-point voltage monitor

The object of this invention is to provide a safe, reliable and flexible method of examining the voltage that exists between any selected pair of points within a power system, or power equipment, without interfering with the normal operation of the power system and giving inherent protection to the personnel carrying out the monitoring task.

The novelty of the invention is in the current differencing method used to measure the voltage together with the circuit interface point chosen for the two part measurement system.

The invention provides a two part multiplexed measurement system capable of measuring voltage between any two points addressed by differencing currents produced by the voltage at those points via resistors into an amplifier system. The amplifier system inherently reproduces a scaled replica of the voltage waveform between the two points addressed at a safe voltage and with respect to safety earth.

The first part of the two part system, referred to as the 'Interface Unit', consists of only passive circuit elements and may be permanently wired into the power system to be monitored. The second part of the measurement system may be located outside the power system equipment case and interconnected to the first part with a multiway plug and socket. This second part contains the amplifier system and the electronic facility to connect the amplifiers to any of the circuits connected to the conductors of the multi-way plug.

An important feature of this invention is that when the interconnecting plug between the two parts of the system is disconnected no conductor of the plug or socket thus exposed has a voltage greater than one volt with respect to safety earth. Furthermore connecting any conductor of the exposed plug or socket to any other conductor of the plug or socket or system earth will not cause damage or malfunction of the power system or the measuring equipment. The use of the novel current differencing technique and the location of the current determining resistors in the first part of the system allows these desirable safety features to be achieved.

The method will be described in conjunction with the accompanying drawings in which:—

Figure 1 shows the principle of current differencing used to measure voltage.

Figure 2 shows the method used to limit the voltage at the multiway plug and socket to less than one volt.

Figure 3 shows the circuit arrangement of the two part multiplexed measuring instrument.

Figure 1 illustrates the basic principles of differencing currents from two voltage points, 1 and 4, in a power system by including known resistors R_1 and R_2 in the circuit between the monitored points and the 'virtual earth' inputs of two separate inverting operational amplifiers. The high internal gain of these inverting amplifiers ensures that, for practical purposes, all of the input current from R_1 and R_2 respectively is diverted through the feedback resistors R_3 and R_5 respectively that are connected from the output terminals of the amplifiers, points 3 and 6, to the 'virtual earth' input terminals of the amplifiers, points 2 and 5 respectively. This results in points 2 and 5 in the circuit remaining at the safety earth potential of line 7; hence the terminology 'virtual earth'. The currents flowing in resistors R_1 and R_2 are therefore proportional to the voltages V_1 and V_2 at points 1 and 4 respectively.

The voltage at the output of amplifier A_1, point 3, will be V_3 where V_3 is given by:—

$$V_3=-(I_1\times R_3)$$

The voltage V_3 is used to create a current I_3 through resistor R_4 which is connected between point 3 and the 'virtual earth', point 5, of amplifier A_2.

If $R_3=R_4$ then:—

$$I_3=-(I_1\times R_3)/R_4=-I_1$$

The total current into the 'virtual earth', point 5 of amplifier A_2 will now be $I_2+I_3=I_2-I_1$ and this current must flow in the amplifier feedback resistor R_5. The voltage developed at the output of amplifier A_2, point 6, with respect to the safety earth line, point 7, is therefore given by:—

$$V_0=-(I_2-I_1)\times R_5=(I_1-I_2)\times R_5$$

Now I_1 is given by V_1/R_1 and I_2 is given by V_2/R_2.

If $R_1=R_2=R_{in}$ then:—

$$V_0=(V_1-V_2)\times R_5/R_{in}$$

Thus the output voltage with respect to safety earth is proportional to the voltage difference between the two points 1 and 4 of the high voltage power system that is being monitored. This output voltage is a scaled replica of the analogue voltage between points 1 and 4 and may be measured conveniently with a voltmeter or fed to a cathode ray oscilloscope for display and examination. An important benefit of this measuring technique is that the waveform may be examined in this way without removing the safety earth from the cathode ray oscilloscope. This would not have been possible if the points 1 and 4 were monitored directly with the oscilloscope. Such direct monitoring of power systems exposes personnel to high voltage terminals with the consequent danger to their personal safety and to the possibility of interfering with the normal operation of the power system. An object of this invention is to preclude such danger.

It should be noted that the currents required to achieve such electronic measurements that have been described are only of the order of micro-

amperes. This means that the input resistors $R_1=R_2=R_{in}$ may be of the order of several megohms and will thus have no deleterious effect on the power circuit that is being monitored.

As already stated an object of this invention is to provide a safe method of monitoring high voltages in power systems. To this end the monitoring system is divided into two parts. One part referred to as the 'Interface Unit' is pre-wired into the power system and terminated at a multiway plug or socket that is accessible from outside the power system enclosure. The second part contains the amplifiers and electronic selection switches to connect the amplifiers to the required pre-wired circuits contained within the interface unit. The choice of a current differencing measurement technique as previously described allows the voltages appearing at the multiway connector between the interface unit and the amplifier unit to be limited to a very low level by means of diode clamping. Figure 2 shows the arrangement for one circuit of the interface unit when connected to the appropriate amplifier. The line XX' represents the connections at the multiway plug and socket between the interface unit and the amplifier unit. Each of the monitor circuits on the interface unit side of the plug and socket is connected to the safety earth line 7 (and 7') via an inverse parallel connected pair of silicon semiconductor diodes, or elements with similar characteristics such as zener diodes.

Resistor R_1 determines the current produced by voltage V_1 into the 'virtual earth', point 2 (and 2'), of the amplifier whilst the inverse parallel diodes D_1 and D_2 ensure that even if the amplifier unit is not connected the voltage existing at point 2 cannot exceed that of a conducting diode which is typically less than one volt. When the multiway plug and socket is connected points 2 and 2' are at the virtual earth potential which is the same as that of the safety earth. Under this condition diodes D_1 and D_2 are high impedance as there is no voltage across them and they therefore have no effect on the performance of the measuring circuit.

Figure 3 shows the circuit arrangement for an 'n' way two part monitoring instrument. Whilst 'n' may be any number it is convenient to consider multiples of 16 as the proprietry analogue multiplexed switches represented by the blocks AM1 and AM2 in Fig. 3 generally cater for 16 channels. These proprietry integrated circuits, such as the type CD4067 supplied by RCA Corporation in the U.S.A., allow the output terminal to be connected to any one of the 16 input lines by the setting of a digital number, in binary form, on the address lines associated with the integrated circuit.

Multiples of these units may be arranged to achieve the capability to address and select from any number of input lines by one skilled in the subject. For clarity the internal pole arrangement within the integrated circuits is represented symbolically within the blocks shown for AM1 and AM2 in Fig. 3.

The output terminals of these selector, or multipexing, units are connected directly to the respective 'virtual earths' of the amplifiers, points VE1 and VE2. The multiway plug and socket between the interface unit and the amplifier unit is again represented by the line XX'. This plug and socket has at least n+1 separate conductors as the safety earth must also be connected from the power equipment that is being monitored to the amplifier unit.

It is seen from Fig. 3 that the circuitry of the interface unit consists solely of passive components, only resistors and diodes are utilised. Each of the monitored points, 1 to 'n', feeds via a series resistor to a conductor of the multiway plug and socket. Each junction of these resistors and the conductors of the multiway plug is connected to the safety earth line via a series element comprising a pair of inverse parallel connected silicon semiconductor diodes. Each of these monitoring circuits are as has been described with reference to Fig. 2. The value of the resistance determines the current per volt whilst the inverse parallel diodes ensure that no voltage greater than one volt can exist at the multiway connector with respect to safety earth even if the plug and socket is not connected.

The current differencing is performed by amplifiers A1 and A2 in the manner that has been described with reference to Fig. 1. In the complete multiplexed measuring system of Fig. 3 AM2 is used to steer the current from one of the monitored circuits at the multiway plug and socket to the virtual earth VE1 of amplifier A1. A1 together with its feedback resistor R_a and the resistor R_b connected from the amplifier output terminal to the virtual earth VE2 of amplifier A2 develops a current of equal magnitude and opposite polarity in resistor R_b to that of the current in the monitor circuit selected by AM2. The multiplexer AM1 is used to steer the current of another of the monitor circuits at the multiway plug and socket to the virtual earth, VE2, of amplifiier A2. The nett current flowing in the feedback resistor R_c of amplifier A2 is thus the difference of the currents produced in the selected monitor circuits. Thus the output voltage V_{o2} of the amplifier A2 is proportional to the difference of the voltages at the selected monitored points.

Claims

1. A two part multiplexed measurement system capable of measuring voltages between any two selected points within a power system by differencing currents produced by the voltages at those points via resistors into an amplifier system which inherently reproduces a scaled replica of the voltge waveform between the two points selected but at a safe voltage with respect to safety earth. The first part of the measuing system comprises of resistors of equal ohmic value connected from the points in the power system that are being monitored to separate conductors on a multiway plug which allows connection to

the second part of the measuring system. All conductors of this interconnecting plug are connected to the safety earth line via parallel connected pairs of semiconductor diodes which limit the voltage appearing at the conductors of the plug of the first part of the measuring system to less than one volt under all conditions. Thus the first part of the measurement system contains only the passive components of the resistors and diodes described. The number of monitoring points may be any number but it is convenient to consider multiples of 16. This first part of the measuring system may be contained within the power system enclosure and prewired to the points to be monitored. The multiway plug may be mounted in the surface of the power system enclosure to allow the second part of the measuring system to be connected to the first part from outside the power system enclosure. The second part of the measuring system comprises known means to select any two conductors of the multiway plug and socket and connect the selected conductors to the 'virtual earth' inputs of two inverting electronic operational amplifiers. The non-inverting inputs of the operational amplifiers are connected to safety earth. A first amplifier monitors the current in one selected circuit and feeds a current of equal magnitude but opposite sign to the 'virtual earth' input of the second inverting electronic operational amplifier. The current from the second selected conductor of the multiway plug and socket is also fed to the 'virtual earth' input of the second operational amplifier. This second operational amplifier produces an output voltage proportional to the total current being supplied to its 'virtual earth' which is the difference of the currents produced in the two selected monitoring circuits by the resistors contained in the first part of the measuring system and the voltages at the monitored points of the power system. The output voltage of this second amplifier is thus a scaled replical of tve voltage difference between the two selected monitoring circuits but at a safe voltage with respect to safety earth.

2. A two part voltage monitoring system as described in Claim 1 in which zener diodes or other devices with similar voltage limiting characteristics are used to restrict the voltage at the conductors of the multiway plug connected to the first part of the measuring system.

3. A two part measuring system as described in Claim 1 and 2 and essentially conforming to the previous description together with the accompanying drawings.

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